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(19)(CA) **APPLICATION FOR CANADIAN PATENT** (12)

(54) Process for Obtaining 2-Hydroxy-4-Methyl Thiobutyric
     Acid (MHA), MHA and Its Use

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ABSTRACT OF THE DISCLOSURE

It is known to isolate MHA from a reaction-mixture obtained by the addition of hydrocyanic acid (HCN) to methyl mercaptopropionic aldehyde (MMP) and the hydrolysis of the methyl mercapto propionic cyanohydrine (MMP-CH) obtained thereby with sulphuric acid, in which the reaction mixture is brought into contact with a substantially non-water-miscible organic solvent in order to form an extraction solution having the solvent and MHA transferred from the reaction mixture, and the MHA is obtained as an extract from this extraction solution by concentration. The simplest and most economical process of the invention concerning the processing of the reaction product which facilitates the production of a highly concentrated product with an extremely low dimer, oligomer and by product content, is characterised in that the concentration is conducted in such a way that the remaining extract contains less than 4 wt % and preferably less than 2 wt % of water. Animal feed supplement, mixtures for supplementing animal feed, e.g. with methionine or ammonium-MHA.

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5 The invention relates to a process for recovering 2-
hydroxy-4-methylthiobutyric acid (MHA) according to the
pre-characterising clause in Claim 1, MHA obtainable in
accordance with the invention and use of the MHA prepared
by this process.

10

The invention relates in particular to an improved, new
type of isolation process for MHA in very high
concentration and purity from a reaction mixture resulting
during preparation.

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2-hydroxy-4-methylthiobutyric acid (MHA) is the hydroxyl
analogue of the essential amino acid methionin in racemic
form and like the latter is an important additive in animal
nutrition. When rearing poultry, MHA shows similar growth
20 stimulating properties to those of the amino acid
recognised for this purpose. The additive is also being
used increasingly in other areas of animal nutrition.

MHA is mostly used in the form of aqueous concentrates,
25 wherein these contain, in addition to the monomer, a
certain proportion of oligomers, mainly dimeric and
trimeric linear ester acids. The actual amount of these
oligomers depends on the conditions of preparation and the
concentration selected. Due to their low nutritive action
30 and the inconvenient effect on the flow properties, due to
an increase in viscosity, it is desirable, however, to keep
their percentage proportion as low as possible. Commercial
formulations preferably have, for a total concentration of
88 - 90 wt.%, up to 24 wt.%, corresponding to ca. 27 mol.%
35 in total of oligomers, corresponding to a monomer/oligomer
ratio of ~3:1.

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Use of the calcium salt and mixed calcium ammonium salt of
MHA as an animal feed additive is also known. Production of
these salts, however, is associated with higher production
costs. In addition, as powdered solids they are less easy
5   to incorporate into the feedstuff formulation than readily
sprayed aqueous concentrates of the free acids with low
proportions of oligomers.

The synthetic route to MHA consists of 3 reactions.
10

The general process for preparing MHA starts from
3-methylthiopropionaldehyde, also called
methylmercaptopropionaldehyde or MMP, which is reacted with
hydrogen cyanide to give 2-hydroxy-4-
15 methylthiobutyronitrile, also called MMP-cyanohydrin or
MMP-CH (equation 1).

$$H_3CS\diagup\diagdown CHO + HCN \rightleftharpoons H_3CS\diagup\diagdown\underset{\underset{OH}{|}}{\overset{\overset{H}{|}}{C}} CN \quad (I)$$
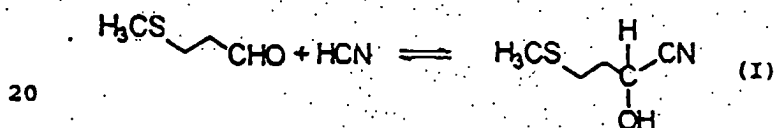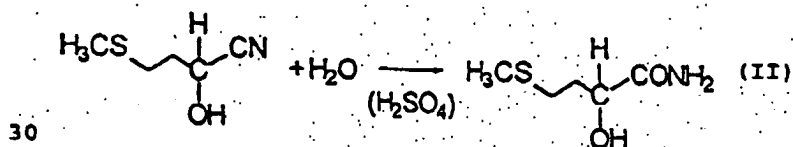
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The MMP-cyanohydrin produced is then usually hydrolysed
with strong inorganic acids via the intermediate stage of
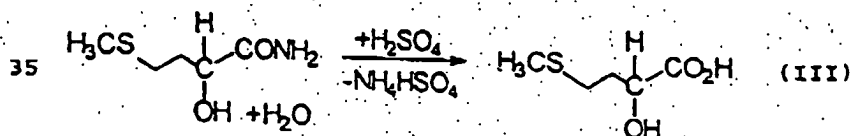2-hydroxy-4-methylthiobutyramide, also called MHA-amide
25 (equation II),

$$H_3CS\diagup\diagdown\underset{\underset{OH}{|}}{\overset{\overset{H}{|}}{C}}CN + H_2O \xrightarrow[(H_2SO_4)]{} H_3CS\diagup\diagdown\underset{\underset{OH}{|}}{\overset{\overset{H}{|}}{C}}CONH_2 \quad (II)$$

30

to give the methionin hydroxy analogue (MHA) (equation
III).

$$H_3CS\diagup\diagdown\underset{\underset{OH}{|}+H_2O}{\overset{\overset{H}{|}}{C}}CONH_2 \xrightarrow[-NH_4HSO_4]{+H_2SO_4} H_3CS\diagup\diagdown\underset{\underset{OH}{|}}{\overset{\overset{H}{|}}{C}}CO_2H \quad (III)$$
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This hydrolysis can be performed in either one or two
stages, wherein "stages" is understood to mean that
inorganic acid and/or water is added either once or twice
to hydrolyse the MMP-CH, i.e. the number of stages
5   corresponds to the number of addition processes.

A two-stage method of working starting from MMP-cyanohydrin
is described in US patents 2 745 745, 2 938 053 and
3 175 000. There, the cyanohydrin is initially reacted at
10 relatively low temperatures with concentrated inorganic
acids, e.g. with 50 - 85 % strength sulphuric acid, to give
MHA-amide, whereupon hydrolysis to give MHA is then
performed at elevated temperature after the addition of
water. The calcium or calcium ammonium salt of MHA and the
15 coupled product calcium sulphate is obtained from this by
treating the saponification mixture with calcium hydroxide
or carbonate. To avoid the inevitable production of
unwanted secondary products, the first two patents
mentioned recommend using the hydrolysis reagent sulphuric
20 acid in a sub-stoichiometric ratio to MMP-cyanohydrin of,
for example, 0.55 - 0.8:1. British patent 722 024, which
describes a similar method of forming the MHA salts from
MHA-amide, also implies the two-stage method of working.

25 A two-stage hydrolysis is also used in the methods
disclosed in European patents 0 142 488 (using sulphuric
acid) and 0 143 100 (using inorganic acids), the object of
which is the recovery of MHA in a liquid form, that is in
highly concentrated aqueous solutions. These are obtained
30 after the hydrolysis reaction, performed under defined
concentration and temperature conditions via the amide
stage using excess inorganic acids, by means of solvent
extraction, wherein specific solvents which are partially
miscible with water are used.
35
According to the data in these patents, the characterising
feature of the method described therein is regarded as the
recovery of MHA from the extraction solution, which is

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performed in such a way that recovery includes removal of
the organic solvent in the presence of at least about 5
wt.% of water, with respect to the remaining extract (MHA).
MHA is recovered from the extraction solution by
5 distillation (see the examples), wherein steam distillation
is preferred. By removing the solvent from the extraction
solution during steam distillation, the bottom product
obtained is a mixture of MHA and water. Steam distillation
is therefore performed in such a way that the bottom
10 product contains at least 5 wt.% of water.

At another point, the patents in question specify that the
column conditions during distillation are controlled in
such a way that throughout the column, at least, however,
15 in the bottom fraction, the liquid phase contains about
5 wt.% of water.

From this, it follows that without the presence of a
sufficient amount of water during recovery of MHA from the
20 extraction solution the increasing formation of unwanted
secondary products (dimers and oligomers) is to be feared.

Furthermore, the steam is used during distillation as a
driving agent for complete removal of the extraction agent
25 from the MHA solution, e.g. by forming a low-boiling
azeotropic mixture with the corresponding extraction agent.

Concentrated MHA solutions without the use of a solvent are
obtained according to US patent 3 773 927 by means of a
30 two-stage hydrolysis of MMP-cyanohydrin using excess
aqueous hydrochloric acid, subsequent concentration of the
saponification mixture and separation of the crystallised-
out ammonium chloride. The MHA concentrates obtained in
this way, however, smell of oligomers and are dark
35 coloured. Also, the isolated ammonium chloride is heavily
contaminated.

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According to US patent 4 353 924, the excess inorganic
acid, after two-stage hydrolysis using hydrochloric acid,
is neutralised with ammonia or another alkaline substance.
Concentrated MHA solutions with very few corrosive
5   properties are obtained in this way.

A process is described in US patent 4 310 690 in which,
after hydrolysis with hydrochloric acid the mixture is
neutralised with caustic soda solution under precisely
10 defined conditions and the ammonium chloride is converted
into common salt and ammonia. During subsequent treatment
with slaked lime, the MHA calcium salt is obtained as a
slurry in a virtually saturated solution of common salt.
After solid/liquid separation, the majority of the filtrate
15 is recycled to prepare the slaked lime slurries. In this
way, pollution of the effluent is reduced and the co-
production of unwanted or environmentally polluting
impurities is avoided.

20 One-stage hydrolysis methods are also described in the
patent literature. Thus, the process according to British
patent 915 193 is aimed at the recovery of the MHA calcium
salt, wherein after saponification of MMP-cyanohydrin with
excess dilute sulphuric acid, the MHA formed is separated
25 from the saponification solution by means of extraction
with high-boiling ethers and the MHA calcium salt is
obtained by subsequent treatment of the extract with
calcium hydroxide. Return of the aqueous raffinate to the
saponification stage which is provided in this continuous
30 process, however, leads to an accumulation of inorganic
minor constituents.

European patent 0 330 527 discloses a further one-stage
hydrolysis process using sulphuric acid as the
35 saponification agent, which takes place without solvents
and leads directly to concentrated aqueous MHA solutions,
wherein crystalline ammonium sulphate in saleable form is
obtained as the co-product. This objective is achieved by

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neutralising the saponification mixture with ammonium hydroxide solution until the excess inorganic acid and the ammonium bisulphate produced have been converted into the neutral sulphate, wherein two liquid phases are produced,
5 which for their part can be separated and evaporated down in order to obtain MHA on the one hand and crystalline ammonium sulphate on the other hand. In this case, the various filtration and recovery steps are combined in such a way that virtually no product is lost and no salt-
10 polluted effluent is produced. The resulting MHA is of similar quality to the product obtained according to EP 0 142 488.

However, even this environmentally friendly process has
15 various disadvantages. As the applicant of the present invention established when reworking this process, as a result of the comparatively high dilution of the sulphuric acid (20 - 50 %) a considerably higher excess of acid than stated has to be used in order to achieve complete
20 cyanohydrin conversion. Also, to avoid the deposition of salt during neutralisation, high dilutions have to be used in order to be able to separate the two liquid phases cleanly. Next, the ammonium sulphate obtained is of a sticky consistency and associated with a penetrating odour
25 so that aftertreatment, such as e.g. wash-filtration or recrystallisation is required, which increases the costs of the process. Again, the process consumes more energy in the evaporation steps than the process in EP-A 0 142 488 which is cited for comparison, differently than is asserted.
30 Solids handling, arranged in two separate lines with filtering/centrifuging and, not shown in the flow-chart, drying of the ammonium sulphate, is also very costly and utilises complex equipment.

35 In view of the prior art cited herein and the disadvantages associated with known processes, the object of the invention is to provide a further process for the preparation of 2-hydroxy-4-methylthiobutyric acid (MHA) of

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the type mentioned at the beginning, which is intended to
be as simple and cost effective as possible with regard to
processing the reaction products and is intended to provide
the most highly concentrated product possible with the
5 lowest possible concentration of dimers, oligomers and
secondary products. The invention thus provides data for an
improved MHA and its use.

This is achieved along with further objects which are not
10 stated in detail by a process of the type mentioned at the
beginning which has the features in the characterising
section of Claim 1.

Advantageous process variants are protected under the
15 process Claims which depend on Claim 1. With reference to
an improved MHA, Claim 8 represents a solution to the
problem according to the invention. Claims 9 and 10 provide
novel uses.

20 Since evaporation of the extraction solution to obtain MHA
as product (remaining extract) is performed in such a way
that the remaining extract contains less than 4 wt.%,
preferably less than 2 wt.%, of water, the invention
provides a process which enables the preparation of liquid
25 MHA of outstanding quality and which in particular produces
in an unforeseeable manner a highly concentrated liquid MHA
with a low proportion of oligomers and dimers. From the
point of view of the known processes in the prior art, in
particular the two European patents 0 142 488 and
30 0 143 100, it has to be recognised as more than surprising
that this can be achieved with smaller amounts of water
than a person skilled in the art would infer from the
patents mentioned. Within the scope of the invention, it
was also, unforeseeably, shown that approximately 100 %
35 strength MHA solutions are obtainable which can be
transported without any clear loss of quality and then
adjusted to desired concentrations with suitable additives

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or diluents. This finding is an enormous economic advantage
for a large-scale process.

The present invention is thus concerned with one important
5   aspect, in particular the evaporation of an extraction
solution, in the form in which it is obtained following
liquid/liquid extraction of a reaction mixture which is
obtained, for example, by hydrolysis of MMP-CH with
sulphuric acid.

10

The extraction solution used for evaporation to recover MHA
can be obtained from the reaction mixture by processes
familiar to a person skilled in the art, for example by
extraction. The organic solvent used for extraction in this
15   process should be essentially immiscible with water.
However, partial miscibility of the organic solvent with
water can be tolerated. Among solvents which are suitable
for material separation in the liquid/liquid extraction
process are a number which satisfy the conditions of
20   chemical inertness and a low solubility towards water. In
general it is preferable that the solubility of water in
the solvent should be not greater than ca. 15 wt.%,
preferably not greater than 10 wt.%, at room temperature.
From among the suitable solvents, those which are preferred
25   have a boiling point between ca. 60°C and ca. 200°C,
preferably between ca. 70°C and 150°C. The partition
coefficient for MHA in equilibrium between the solvent,
which contains the extracted MHA, and the aqueous
raffinate, which remains behind after the solvent and the
30   MHA hydrolysate are placed in contact, should be at least
ca. 2. This partition coefficient should preferably be at
least 5. Also, the partition coefficient for MHA in
equilibrium between extraction solution and wash water
should not be less than about 1. Furthermore, the solvent
35   should have low toxicity.

A number of ketones, aldehydes and carboxylates are
particularly suitable as a solvent in the extraction

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process. Particularly preferred solvents are ketones with
comparatively low molecular weights such as, for instance,
methyl-n-propyl ketone, methylethyl ketone, methylamyl
ketone, methylisoamyl ketone, methylisobutyl ketone,
5 ethylbutyl ketone and diisobutyl ketone. Highly suitable
solvents for the extraction process are also aldehydes such
as, for instance, n-butyraldehyde, and esters such as, for
instance, ethyl acetate, n-butyl acetate, n-propyl acetate
and isopropyl acetate. Alcohols may also be used, although
10 these are less preferred due to their mutual solubility
with water, slow phase separation and the tendency to react
with MHA.

The extraction itself may basically be performed
15 continuously or intermittently. For a batchwise process, a
stirred tank reactor, for instance, is suitable.
Preferably, however, the extraction is performed in a
continuous countercurrent extraction plant which has an
extraction zone designed to accelerate the mass transfer
20 between solvent and aqueous phase. Thus, it is
advantageous, for example, to perform the extraction in a
cascade of continuous countercurrent mixer/separators, a
packed column, a perforated plate column, preferably as a
pulsed column or a column with movable perforated plates, a
25 column with rotary plates or a centrifugal extractor. In a
particularly preferred embodiment the extraction is
performed in a perforated plate column for liquid/liquid
extraction. Intermittent or pulsed currents, although
cyclical and thus not continuous in the sense of rapid flow
30 rates, are regarded as "continuous" in connection with the
present disclosure.

The extraction process is preferably controlled in order to
produce and maintain the solvent phase in the extraction
35 zone as the continuous phase.

In order to keep the salt content of the final product to a
minimum, the extract is preferably washed with water. In a

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continuous countercurrent extraction system, the extract
can be washed by mixing with water at a point which is
upstream, with reference to the direction of the organic
current, of the point at which the hydrolysate is
5   introduced into the liquid/liquid extraction system. Thus,
for example, in a vertical column and using a solvent whose
specific weight is preferably less than 1, solvent is
introduced into the column at a point below the feed point
at which the aqueous hydrolysate solution is introduced and
10 wash water is introduced to the column at a point above the
feed point for the hydrolysate solution. In a preferred
embodiment, the solvent is supplied at a rate of about 0.5
to 0.6 parts by weight per unit of weight of hydrolysate,
when an extract with a specific weight of about 0.92 to
15 0.97 and a total MHA concentration (total MHA = sum of MHA
monomers, dimers + oligomers + optional MHA-amide) of 35 to
40 wt.% is obtained.

The productivity of the extraction process is increased by
20 operating at a slightly elevated temperature, by providing
a relatively low viscosity for the solvent phase within the
extraction system. Operating at a temperature in the range
of about 50 to about 80°C also produces a slightly
beneficial effect on the MHA partition coefficient between
25 the organic and the aqueous phase.

In the scope of the invention, MHA can be recovered from
the extraction solution by evaporation, as already
mentioned. In a particularly preferred embodiment according
30 to the invention, the organic solvent is removed by
evaporation by using a unit which allows a short residence
time for the extraction solution in an evaporation stage.
Therefore the organic solvent is particularly preferably
separated from the extraction solution during evaporation
35 by using a falling-film evaporator, thin layer evaporator
and/or short-path evaporator or with the aid of this type
of unit.

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The expression "with the aid of this type of unit" is
understood to mean, within the scope of the invention, that
the unit mentioned with a short residence time for the
extraction solution may also be combined with devices known
5 to a person skilled in the art for separating solvents from
extraction solutions. In this case, the units used to form
the combination do not necessarily have to be those with a
short residence time. At this point may be mentioned, inter
alia, distillation columns which may be equipped for the
10 introduction of steam or other suitable stripping agents,
as required. Combinations which include several of the
units with short residence times listed are also possible.

In an advantageous modification of the process according to
15 the invention, the evaporation procedure is preferably
operated in such a way that the smallest possible residual
amount of solvent is produced. This is achieved, for
example, by combining several of the units mentioned above
with a stripping stage, which may be present as an
20 additional unit or integrated into the previously mentioned
units in the evaporation system such as, for instance, via
direct introduction of the stripping medium into such an
evaporator.

25 The specific conditions for evaporation necessarily vary
with the particular solvent used for application in the
extraction process. Basically, when using a separation unit
with a short residence time for the evaporation process, it
is preferred that the pressure during evaporation is not
30 higher than 600 mbar, preferably 400 mbar and in particular
200 mbar.

The temperature to be used for evaporation generally
depends on the solvent being separated. It is striven,
35 however, and is thus also particularly preferred in the
scope of the invention, to keep the temperature during
evaporation no higher than 150°C. If this temperature is
very clearly exceeded, then the desired product may be

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subject to thermal damage. Here, the temperature during
evaporation is not necessarily understood to be the contact
temperature of the product with the surface of the
evaporation unit designed for short-term contact with the
5 product. Rather, the temperature during evaporation is to
be thought of as the average temperature in the evaporation
unit. The temperature at the surface of the evaporation
unit may, if necessary, be very much higher than 150°C. The
brevity of contact time in the evaporation units used is
10 the crucial factor. This avoids thermal damage, even if the
contact temperature should be well above 150°C.

With regard to temperature distribution, it has proven in
the scope of the invention that it is of special advantage
15 for product quality if the temperature of the remaining
extract directly at the outlet from the evaporation unit is
between 30 and 100°C, preferably 50 to 95°C and in
particular 70 to 90°C.

20 As already mentioned, the residence time of the remaining
extract is a crucial factor for the quality and composition
of the MHA product striven for. In an advantageous
development of the process according to the invention, the
residence time of the remaining extract in the evaporation
25 unit is not longer than 1.5 hours. This refers to the
residence time in the whole evaporation system, which has
at least one evaporation stage with a very short residence
time. The residence time in the unit with a very short
residence time is more likely to be within the minute range
30 or less as against the maximum total residence time of
1.5 h cited. In this case, it is preferred in the scope of
the invention, when evaporation consists of only a thin
layer evaporator and/or a falling-film evaporator and/or a
short-path evaporator, that the residence time in these
35 units is not longer than 1 h, preferably 40 min.

In a further aspect, the process according to the invention
also improves, in addition to the isolation procedure for

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MHA from the reaction mixture obtained by hydrolysis with
sulphuric acid, the hydrolysis of MMP-CH itself. Thus, in a
preferred embodiment according to the invention, hydrolysis
of MMP-CH is performed in such a way that in a first stage
5 the MMP-CH is hydrolysed with 60 - 85 wt.% strength,
preferably 65 - 80 wt.% strength, sulphuric acid in the
molar ratio of MMP-CH to H_2SO_4 of 1.0:0.5 to 1:1.05,
preferably 1:0.6 to 1:0.8 at temperatures of 30 - 90°C,
preferably 50 - 70°C, essentially with the production of
10 MHA-amide. Here, essentially MHA-amide is produced from
MMP-cyanohydrin, wherein the mixture being produced is
essentially free of unconverted MMP-cyanohydrin. In other
words, this means that the hydrolysis proceeds virtually
quantitatively.
15

Furthermore, it is particularly advantageous to the
invention if hydrolysis of the MHA-amide obtained in the
first stage is carried out in a second stage by adding
water and if necessary further sulphuric acid up to the
20 stoichiometric upper limit, preferably however without the
further addition of further H_2SO_4, at temperatures up to
140°C, preferably between 100 and 140°C, preferably under
reflux conditions, in order to complete hydrolysis of the
MHA-amide to give MHA. Basically, the second hydrolysis
25 stage can also be performed at temperatures below 100°C,
for example up to upper limits of temperatures of 90 -
100°C. In this case, however, the addition of further
sulphuric acid up to a maximum of the stoichiometric upper
limit, is required. In order to complete hydrolysis of the
30 MHA-amide to give the desired MHA without adding further
sulphuric acid, but only adding water, it has proven
advantageous to the invention to use temperatures up to
140°C. It is also within the scope of the invention to
perform the intermediate hydrolysis of MMP-cyanohydrin
35 with, as compared with the prior art, more highly
concentrated sulphuric acid in substoichiometric up to at
most stoichiometric ratios, wherein in the case of
substoichiometric addition in the first hydrolysis stage

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(amide formation) at lower temperature, to shorten the
reaction time in the second stage, further sulphuric acid
may optionally be added to reach the stoichiometric upper
limit at elevated temperature, in order to complete
5   conversion of the amide to the acid.

The invention also provides an improved MHA, which is
obtainable by a process like the one described above. The
improved MHA is characterised according to the invention in
10   that it has more than 95 wt.% of total MHA where total MHA
= the sum of monomeric MHA, MHA dimers and MHA oligomers
and between more than 0.1 and less than 5 wt.% of water. In
particular, it has proved advantageous to the invention
that an MHA can be obtained, without a high degree of
15   impairment in quality, which is characterised in that it
has more than 98 wt.% of MHA as the sum of monomeric MHA,
MHA dimers and MHA oligomers and a water content of between
0.1 and less than 2 wt.% and a kinematic viscosity of
> 100 mm²/s at 25°C. Surprisingly, it has been demonstrated
20   that the kinematic viscosity, measured by the Cannon-Fenske
method, of the highly concentrated concentrate (that is MHA
with at least 98 wt.% of active substance), after storage
and dilution, is comparable with the kinematic viscosity of
an 88 wt.% strength product. Despite a relatively high
25   dimer and oligomer content of ca. 50 wt.% being set up in
the concentrate after storage for ca. 300 days at room
temperature, on dilution of the stored concentrate with
water to ca. 88 wt.% its kinematic viscosity corresponds to
that of the 88 wt.% strength commercial product which in
30   corresponding storage tests has an equilibrium
concentration of only ca. 25 wt.% of dimers and oligomers.
In both cases, with both the diluted concentrate and the
commercial product, the equilibrium state was reached. This
fact is very surprising and is proven to be of great
35   advantage for a variant of the MHA concentrate prepared
according to the invention. In view of the fact that
dimeric and oligomeric fractions generally impair the
viscosity of the MHA which in practice is disadvantageous

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for practical processing, it was all the more surprising
that, despite high initial contents in the so-called highly
concentrated concentrate, an easily pumpable and thus
transportable mixture with a convenient viscosity can be
5   obtained. This has a number of advantages. In particular,
the viscosity and above all the high active substance
content mean that the concentrate can be transported more
economically, since less water is transported, and yet
nevertheless it can be diluted with water to standard
10 concentrations in the food mill at the destination, without
having to put up with unacceptably high viscosities.

Furthermore, it has turned out, within the scope of the
invention, that an especially high quality MHA is
15 obtainable following appropriate management of the
hydrolysis reaction combined with the mild evaporation
procedure used according to the invention with very short
residence times. The MHA which can be particularly
advantageously prepared is characterised in particular by a
20 proportion of the sum of dimers and oligomers with respect
to the total amount of MHA of ≤ 10 mol-%, preferably
< 7 mol-%. This means that, as compared with the prejudice
which is widespread in the prior art, a highly concentrated
MHA is obtainable which represents a form which is very
25 suitable for transport due to the extremely small
proportion of dimers and oligomers. For an extended time of
shipment, it may sometimes be necessary to convert the
dimers and oligomers which are formed to an increasing
extent, depending on the storage time, into monomer MHA
30 again by the addition of water and the effect of elevated
temperature.

Furthermore it is possible, within the scope of the
invention, to use the highly concentrated MHA product to
35 produce animal feedstuff supplements. In this case, it is
shown that, by admixing the MHA concentrate with water,
methionin and/or salts of MHA (preferably ammonium MHA)
(optionally NH_3 to produce NH_4-MHA), all the nutritive

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values basically required by the market can be produced
without any loss in quality.

Above all it has proved extremely surprising that, by
5   performing the invention, the mixtures are obtainable not
only by the addition of suitable mixing components such as
water, methionin and/or ammonium MHA at the outlet for the
desired MHA product from the evaporation stage, but that
also and furthermore of particular advantage in the event
10   that ammonium MHA is admixed, ammonia can be introduced
directly into the MHA product from the evaporation stage.
In this case, a desired proportion of the MHA is converted
into ammonium MHA, depending on the amount of ammonia
added.
15
Furthermore, it has proved to be particularly advantageous
that a product based on the extraction solution which
contains virtually no dimers or oligomers is obtainable if
ammonia is added to the extraction solution before
20   evaporation and the two phases produced are separated into
an organic and an aqueous phase and the aqueous phase is
fed to the evaporation unit which preferably has a short
residence time. With this method of operation, a mixture of
MHA and ammonium MHA is produced at the outlet from the
25   evaporation stage which contains virtually no dimers and
oligomers. Furthermore, it is also possible to feed ammonia
directly into the evaporation unit. In addition ammonia may
also be used as a stripping medium.

30   In a particularly preferred embodiment according to the
invention, the MHA obtainable by a process described
herein, which contains more than 98 wt.% of MHA, calculated
as the sum of monomeric MHA, MHA dimers and MHA oligomers,
as well as more than 0.1 and less than 2 wt.% of water and
35   having a kinematic viscosity of > 100 mm^2/s at 25°C, is
used to prepare mixtures for animal feedstuff supplements,
wherein the use is characterised in that a mixture is
prepared with methionin, whose MHA content including

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monomers, dimers and oligomers is < 80 wt.% and whose
oligomer content including MHA dimers and oligomers after
storage for 300 days at room temperature is < 25 mol.%,
with respect to the total active substance content of MHA,
5   dimers and oligomers and methionin.

The mixtures of MHA and methionin are animal feedstuff
supplements with outstanding properties. With regard to
methionin on its own, it is known that in practice it is
10   barely soluble or even insoluble in all organic solvents
(even in water). According to the invention, it was
especially surprising that methionin dissolved well in MHA,
even at room temperature. Furthermore, it is known from
commercial 88 wt.% strength MHA, that an ca. 25 mol-%
15   equilibrium concentration of dimers and oligomers is set up
in 300 day storage tests at room temperature. As already
mentioned above, the highly concentrated MHA has a much
higher dimer and oligomer content of ca. 50 mol-% after a
storage time of 300 days. When studying mixtures of
20   methionin and MHA in the storage tests, it has been shown,
surprisingly, that after 300 days storage time, in an
advantageous manner, a significantly smaller proportion of
oligomers and dimers is present. This is, for example,
20 mol-% after 300 days, wherein this still has to be
25   corrected for the methionin substitution for MHA, which
leads to a change in the value to ca. 21.5 mol-%.
Nevertheless, this improvement is significant because a
lower oligomer content is required due to the less
favourable biological efficacy of the monomers. Even an
30   improvement of "only" 3.5 mol-% can lead to a significant
improvement in the efficacy of the product in animal
feedstuff supplements. In particular, the tendency towards
improved activity is crucial. In addition, the cold storage
stability of mixtures of MHA and methionin, surprisingly,
35   is greatly improved. A mixture of 78 wt.% of MHA and
10 wt.% of methionin at -20°C shows no tendency whatsoever
to crystallise after 4 weeks (thus no substance
precipitates out), which is surprising because methionin in

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other solvents under comparable conditions, precipitates
immediately. Current market products with ca. 88 wt.% of
MHA content begin to precipitate at -20°C after 3 to 21
days. Thus, in an advantageous manner, the mixtures of
5   methionin and MHA do not require the use of supplementary
heating to a certain extent when being transported for
prolonged periods under cold conditions. Also storage under
corresponding cold conditions is considerably simpler
because costly additional heating is not required. In
10 addition it is noteworthy that MHA enhances the methionin
additive with regard to biological efficacy. This is novel
and surprising because to date no methionin-containing MHA
liquid formulations have been disclosed and the
availability of such mixtures would not have been
15 immediately obvious to a person skilled in the art, due to
the unexpected solubility of methionin in MHA. In
particular, a mixture of MHA and methionin is the first
liquid feedstuff supplement with a biological efficacy
which is greater than that of the only known liquid
20 feedstuff additives based on MHA.

In yet another preferred embodiment, the invention provides
the use of MHA as it is obtainable from a process as
described above, for preparing mixtures for animal
25 feedstuff supplements, wherein the use is characterised in
that a mixture is prepared using gaseous ammonia, aqueous
ammonia and/or ammonium MHA, whose MHA content, including
monomer, dimers and oligomers is < 80 wt.% and whose
oligomer content including MHA dimers and oligomers, after
30 storage for 30 days at 40°C, is < 25 mol-%, with respect to
the total active substance content of MHA, dimers, and
oligomers. With regard to storage-stability at room
temperature or during cold storage, mixtures of MHA and
ammonium MHA also demonstrate astonishing advantages as
35 compared with pure MHA, wherein these advantages, like
those of mixtures of MHA and methionin, could not have been
easily foreseen. In particular, ammonia has an advantageous

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effect on the position of the equilibrium between monomers, dimers and oligomers.

The invention is explained in more detail in the following
5 by making use of examples which refer to the enclosed figure.

The figures show:

Figure 1   a schematic overview of part of a large-scale
10   plant for recovering MHA, wherein for simplicity
               only the working-up section is shown.

Figure 2   a plot of the Canon-Fenske kinematic viscosity
           for highly concentrated MHA (ca. 98 wt.%) stored
15   for 300 days, as compared with an 88 wt.%
               commercial product, as well as an MHA solution
               adjusted to 88 wt.% MHA by using water to dilute
               a concentrate which has been stored, at different
               temperatures.

20
Figure 3   a representation of the variation in
           concentration of MHA and dimers + oligomers
           during the storage of MHA concentrate (ca.
           98 wt.%) for 300 days at room temperature.

25
Figure 4   a representation of the variation in
           concentration of MHA and dimers + oligomers in
           mol-% during the storage of MHA (88 wt.%) for 300
           days at room temperature.

30
Figure 5   a representation of the variation in MHA +
           methionin, dimers + oligomers and the methionin
           content in mol-% during the storage of MHA
           mixtures of 78 wt.% of MHA and 10 wt.% of
35   methionin for 300 days at room temperature.

Fig. 6   a representation of the variation in MHA +
           ammonium MHA, dimers + oligomers, and ammonium

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MHA content in mol-% during the storage of MHA
mixtures of 78 wt.% MHA + 10 wt.% of ammonium MHA
for 30 days at 40°C.

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Examples

Analytical methods of determination and definitions

10 The concentrations of MMP-cyanohydrin, MHA-amide, MHA
    monomers and methionin were quantitatively determined in
    the process solution by HPLC by means of comparison with an
    external standard (pure substance).

15 The concentration of total MHA = (tot. MHA) = MHA-amide
    (optional) + MHA monomer + MHA (dimers + oligomers) +
    methionin (optional)

    was determined by titrimetric determination of the
20 thioether function using a $KBr/KBrO_3$ standard solution and
    expressed as the sum of the corresponding MHA monomer
    equivalents in [wt.%] or [g] or [mol] or [mol-%].

    The concentration of MHA dimers + MHA oligomers (DIM + OLI)
25 was determined by calculating the difference between total
    MHA and MHA monomer + (optional MHA-amide and/or methionin)
    and expressed as the sum of the corresponding MHA monomer
    equivalents in [wt.%] or [g] or [mol] or [mol-%].

30 The water content was determined by Karl-Fischer titration,
    the MIBK content by GC or a difference sum, the sulphate or
    ammonium content by ionic chromatography using standard
    methods.

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Example 1

In a set of experiments, it was investigated to what extent
MMP-cyanohydrin is converted into MHA-amide on contact with
5 aqueous sulphuric acid under various conditions.

Performing experiment 1

141 g (1.03 mol) of 65 % H_2SO_4 at 50°C were initially placed
10 in a 1 l three-necked flask with a reflux condenser,
dropping funnel, internal thermometer and magnetic stirrer
and 138 g (1.0 mol) of 95 % MMP-cyanohydrin were added
dropwise over 30 minutes with stirring. After a further 15
min post reaction time at this temperature, MMP-cyanohydrin
15 could no longer be detected in the reaction solution.

Performing experiment 2

Experiment 2 was performed in the same way as experiment 1
20 using 72 g (0.55 mol) of 75 % H_2SO_4 and 138 g (1.0 mol) of
95 % MMP-cyanohydrin. After 150 min post reaction time,
0.1 % of the theoretical amount of MMP-cyanohydrin could
still be detected.

25 Performing experiment 3

155 g (1.03 mol) of 65 % H_2SO_4 and 138 g (1.0 mol) of 95 %
MMP-cyanohydrin were simultaneously supplied over 15
minutes at a temperature of 50°C to a 1 l four-necked flask
30 with a reflux condenser, two dropping funnels, an internal
thermometer and a magnetic stirrer. After a further 15 min
post reaction time at this temperature, MMP-cyanohydrin
could no longer be detected.

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Performing experiments 4 - 11

Experiments 4 - 11 were performed in the same way as
experiment 3 with the reaction parameters and results
5   summarised in Table 1.

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Table 1

Expt. No.	Molar ratio MMP-CH:H$_2$SO$_4$	H$_2$SO$_4$ conc. (wt.%)	Reaction temp. (°C)	Reaction time (min) to 0% MMP-CH	to > 0.3 % MMP-CH	Feed time for MMP-CH[1] and H$_2$SO$_4$[2] (min)	Post reaction time final sample	Residual MMP-CH in mol-%
1	1:1.03	65	50	<15	-	30[1]	30	0
2	1:0.55	75	50	>150	- 60	30[1]	150	0.1
3	1:1.03	65	50	<15	-	15[2]	15	0
4	1:0.55	75	50	>75	- 60	15[2]	75	0.15
5	1:0.55	75	90	>105	- 15	15[2]	105	0.07
6	1:1.03	65	90	0	-	15[2]	15	0
7	1:0.55	75	50-90	~ 20-30	- 10-15	15[2]	30	0
8	1:0.6	75	50	>75	- 30-40	15[2]	75	0.05
9	1:0.65	76.4	50	>45	- 15	15[2]	45	0.14
10	1:0.7	78.9	50	5-10	<5	15[2]	15	0
11	1:1.03	75	50	0	0	15[2]	15	0

Reaction conditions

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As shown in Table 1, complete conversion of MMP-CH was found within the stated reaction times in experiments 1, 3, 6, 7, 10 and 11.

5   The reaction time required for complete conversion of MMP-CH with H_2SO_4 increases with increasing molar ratio of MMP-CH to H_2SO_4 (compare experiments 8 and 11). The different sequences of addition of the substances used which was practised here ([1] or [2]) had no serious effect on the
10   reaction results (compare experiments 1 and 3 or 2 and 4).

Example 2

Performing experiment 1
15

35.8 g (0.35 mol, 0.7 mol equ.) of 96 % H_2SO_4 in a 500 ml three-necked flask with a reflux condenser, dropping funnel, internal thermometer and magnetic stirrer were diluted with water to a sulphuric acid concentration of
20   78.9 wt.% H_2SO_4. Over the course of 23 minutes, with stirring, 67.5 g (0.5 mol) of 97.2 % MMP-CH were added dropwise at a temperature of 49 - 56°C. After a further 20 min post reaction time at ca. 50°C, complete conversion of cyanohydrin (0 wt.%) to MHA-amide (66.2 wt.%) was
25   confirmed by means of HPLC analysis. The contents of the flask were transferred by means of 42.3 g of water to a 200 ml steel autoclave with a glass insert, internal temperature measuring device, manometer and magnetic stirrer so that the concentration of the
30   aqueous sulphuric acid present in the reaction mixture was 44 wt.%.

After sealing the autoclave, the reaction mixture was taken to a reaction temperature of 140°C over the course of 45
35   min and stirred at this temperature for another 120 min. After cooling and opening the autoclave, 150.4 g of MHA hydrolysate were obtained. A total amount of 71.5 g (0.48 mol, 95.2 % of theoretical yield) of MHA were obtained, as

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measured by titration of the sulphuric acid equivalents
with bromide/bromate solution. 57.5 g (76.6 % of
theoretical) of MHA monomer were found by means of HPLC
analysis. By difference, this gives 14.0 g (18.6 % of
5 theoretical) of MHA (dimers + oligomers), each expressed as
MHA monomer. MHA-amide could no longer be detected by means
of HPLC.

Performing experiments 2 - 5
10

Experiments 2 - 5 were performed in the same way as
experiment 1, with the reaction parameters and results
summarised in Table 2. In experiment 4, the 1st stage was
performed in a 2 l glass flask, the 2nd stage in a 2 l
15 autoclave, in experiment 5 both stages were performed in a
2 l glass flask.

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Table 2
1st stage: MHA-amide formation

Expt. No.	97.2 % MMP-CH [g] [mol]	96 % H₂SO₄ [g]	H₂SO₄ [mol equ.]	Aqu. H₂SO₄ [wt.%]	Temp. [°C]	Time for addition . reaction [min]	Conc. of MHA-amide [wt.%]	Conc. of MMP-CH [wt.%]
		Reaction conditions					Results	
1	67.5 0.5 mol	35.8	0.7	78.9	49 - 56	23 / 20	66.2	0
2	67.5 0.5 mol	35.8	0.7	78.9	49 - 56	23 / 20	66.2	0
3	67.6 0.5 mol	28.1	0.55	75	46 - 56	35 / 20	67.8	0
4	404 3.0 mol	168.6	0.55	75	45 - 50	35 / 30	n.d.	n.d.
5	269.7 2.0 mol	204.1	1.0	65	50	60 / 30	43.6 + 6.4 MHA	0

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Table 2 continued
2nd stage: MHA hydrolysate formation

	Reaction conditions			Results [% of th.]			
Expt. No.	Aqu. H₂SO₄ [wt.%]	Temp. [°C]	Time [min]	MHA-amide[1]	Total MHA[2]	MHA-mono[1]	MHA dimers + oligomers[3]
1	44	56 - 140 / 140	45 / 120	0	95.2	76.6	18.6
2	44	56 - 140 / 140	65 / 60	0	97.5	78.6	18.9
3	44	56 - 140 / 140	35 / 120	3.8	99.1	76.4	18.9
4	24.3	50 - 100 / 100 / 100 - 140 / 140	18 / 60 / 57 / 90	1.4	95.0	88.1	5.5
5	43	50 - 90 / 90	15 / 120	0.2	99.6	90.1	9.3

1) HPLC
2) Bromide/bromate titration
3) Difference calculated from 1) and 2)

n.d. = not determined

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Example 3

Isolating highly concentrated MHA from MHA hydrolysate by
means of liquid/liquid extraction and evaporating the
5   extraction solution.

Process description making reference to figure 1

Figure 1 shows a schematic diagram of the apparatus used
10 for example 3. This comprises essentially the following
apparatus

Extraction column (001) = pulsed perforated plate column,
                           3 m long, 2.1 cm internal
15   diameter, 60 perforated plates,
                           heated double-walled jacket

Thin layer evaporator   = Sambay evaporator with 0.08 m^2
(002)   exchange area, heated double-
20   walled jacket.

Condensation system   = water-cooled glass condenser
(003)

25 Collection containers for recycled water and solvent
(004/005)

The MHA hydrolysate leaving the MHA hydrolysis stage which
consists essentially of MHA (monomer + dimers + oligomers +
30 optional amide), $(NH_4)_2SO_4$ and/or NH_4HSO_4 and water, is fed
to a level above the 40th plate in extraction column 001,
after being preheated to the extraction temperature. The
solvent (here methylisobutyl ketone = MIBK), also
preheated, is pumped in at the bottom of the column
35 (countercurrent principle). In addition, the head of the
column is supplied with wash water. The raffinate,
containing essentially $(NH_4)_2SO_4$ and/or NH_4HSO_4 and water, is
withdrawn at the bottom of the column. The extraction

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solution containing essentially MHA, solvent and water is
abstracted at the head of the column and then fed to the
Sambay evaporator 002. There, MIBK and H_2O are removed
together from the extraction solution by applying a vacuum
5 and blowing in additional H_2O vapour, as well as a current
of N_2 just in front of the outlet from the evaporator. The
evaporation process was operated in such a way that
< 2 wt.% of H_2O could be detected at the Sambay outlet
(Karl Fischer titration) and the highly concentrated MHA
10 being discharged was virtually solvent-free.

The solvent/water mixture emerging from evaporator 002 was
first condensed in 003 and then taken to a separation
vessel for separation. Solvent and water were each
15 collected in a collection container, 004 and 005
respectively, and from there returned to the extraction
system. The Sambay discharge, cooled to room temperature,
was taken to a product collection container.

20 The conditions and results of the individual experiments
1 - 4 are tabulated in the following summary.

The composition of the extraction solution was analysed
immediately after leaving the head and the composition of
25 the raffinate solution was analysed immediately after
leaving the bottom of extraction column 001.

The composition of the highly concentrated MHA was
determined in the Sambay discharge directly after leaving
30 the discharge point.

The MHA hydrolysate solutions used for extraction were
prepared in a pressure-stabilised 400 l stirred tank from
114.7 kg (874 mol) of MMP-cyanohydrin and 85.7 kg (874 mol,
35 1.00 mol equ.) of H_2SO_4 under the conditions given in
example 2, experiment 5 or from 142.9 kg (1089 mol) of MMP-
cyanohydrin and 110.0 kg (1122 mol, 1.03 mol equ.) of H_2SO_4
under the conditions in example 2, experiment 5 or from

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115.3 kg (879 mol) of MMP-cyanohydrin and 47.5 kg (484 mol, 0.55 mol equ.) of H_2SO_4 under the conditions in example 2, experiment 4. Optionally present highly volatile secondary products were removed from the crude hydrolysate solutions
5 by applying a vacuum after the end of each reaction and the solutions were then analysed. The compositions of the MHA hydrolysates thus obtained and which were used for extraction are given for each of the individual experiments in example 3.
10
Preparation of highly concentrated MHA

Experiment 1

15 Feedstock of MHA hydrolysate from MMP-cyanohydrin and 1.0 mol equ. of H_2SO_4.

Feedstock used for extraction:

20 Mass flows   - MIBK   5 kg/h
                  - MHA hydrolysate   8.4 kg/h
                  - total MHA   3.4 kg/h
                  - wash H_2O 0.5 kg/h
                  - MIBK/hydrolysate   0.6 [-]
25

Composition of the MHA hydrolysate:
(prepared in the same way as in example 2, experiment 5)

- tot. MHA: 42 wt.%; MHA 90 mol-%; dimers + oligomers
30   10 mol-%
- H_2O: 28.9 wt.%
- SO_4^{2-}: 25.9 wt.%

Extraction (001):
35 Temperature: 60°C (average)
Compositions
- of the extraction solution: MIBK   47 wt.%
                              tot. MHA 40 wt.%

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- of the raffinate: H₂O   13 wt.%
                                tot. MHA   0.1 wt.%

Evaporation (002):
5 Pressure: 100 mbar
   Sambay - temperature   in the heating jacket: 150°C
                                at the head: 62°C
                                at the bottom: n.d.
      - stripping steam: 0.5 kg/h
10   - N₂ stripping gas   100 l/h
      - composition of highly concentrated MHA at bottom
         discharge: tot. MHA 98 wt.%; MHA 86 mol-%
                              dimers + oligomers 14 mol-%
                              H₂O: 2 wt.%
15   MIBK: 40 ppm

About 3.5 kg/h of MHA concentrate with the composition
given above were obtained at the bottom Sambay discharge
point.
20

Experiment 2

Feedstock of MHA hydrolysate from MMP-cyanohydrin and
25 1.03 mol equ. of H₂SO₄.

Feedstock used for extraction:

Mass flows   - MIBK   3.6 kg/h
30   - MHA hydrolysate 5.38 kg/h
                  - total MHA   2.10 kg/h
                  - wash H₂O   0.5 kg/h
                  - MIBK/hydrolysate 0.67 [-]

35 Composition of the MHA hydrolysate:
   (prepared in the same way as in example 2, experiment 5)

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- tot. MHA: 39.0 wt.%; MHA 86.9 mol-%; dimers + oligomers
  13.1 mol-%
- H_2O: ca. 30 wt.% (residue)
- SO_4^{2-}:   25.4 wt.%
5 - NH_4HSO_4:   30.4 wt.%

Extraction (001):
Temperature: 54°C (average)
Compositions
10 - of the extraction solution: MIBK   ≤ 54 wt.%
                               tot. MHA   34.1 wt.%
                               H_2O 11.9 wt.%
- of the raffinate: tot. MHA   0.3 wt.%
                               SO_4^{2-} 30.4 wt.%
15   MIBK   0.17 wt.%

Evaporation (002):
Pressure: 100 mbar
Sambay - temperature   in the heating jacket: 150°C
20   at the head: 65°C
                        at the bottom: 92°C
- stripping steam: 0.7 kg/h
- N_2 stripping gas 100 l/h
- composition of highly concentrated MHA at bottom
25   discharge: tot. MHA 99.2 wt.%; MHA 86.9 mol-%
                 dimers + oligomers 13.1 mol-%
             H_2O: 0.8 wt.%
             SO_4^{2-} : 0.43 wt.%
             MIBK: 28 ppm
30

About 2.1 kg/h of MHA concentrate with the composition
given above were obtained at the bottom Sambay discharge
point.

35 Experiment 3

Feedstock of MHA hydrolysate from MMP-cyanohydrin and
0.55 mol equ. of H_2SO_4.

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Feedstock used for extraction:

Mass flows
- MIBK   3.6 kg/h
- MHA hydrolysate   6.55 kg/h
- total MHA   2.62 kg/h
- wash H_2O 0.5 kg/h
- MIBK/hydrolysate   0.55 [-]

Composition of the MHA hydrolysate:
(prepared in the same way as in example 2, experiment 4)

- tot. MHA: 40 wt.%; MHA 94.7 mol-%; dimers + oligomers
  5.3 mol-%
- H_2O: ca. 40.2 wt.%
- SO_4^{2-}:   13.9 wt.%
- NH_4^+:   4.85 wt.%

Extraction (001):
Temperature: 52°C (average)
Compositions
- of the extraction solution: MIBK   ~49 wt.%
                              tot. MHA   35.8 wt.%
                              H_2O 14.9 wt.%
- of the raffinate: tot. MHA   0.13 wt.%

Evaporation (002):
Pressure: 100 mbar
Sambay - temperature   in the heating jacket: 150°C
                        at the head: 59°C
                        at the bottom: 92°C
- stripping steam: 0.6 kg/h
- N_2 stripping gas   100 l/h
- composition of highly concentrated MHA at bottom
  discharge: tot. MHA 98.8 wt.%; MHA 95.1 mol-%
                              dimers + oligomers 4.9 mol-%
            H_2O: 0.5 wt.%
            SO_4^{2-}:   0.18 wt.%
            MIBK: 477 ppm

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About 2.7 kg/h of MHA concentrate with the composition
given above were obtained at the bottom Sambay discharge
point.

5   Experiment 4

Feedstock of MHA hydrolysate from MMP-cyanohydrin and
0.55 mol equ. of H_2SO_4.

10   Feedstock used for extraction:

Mass flows   - MIBK   3.6 kg/h
                - MHA hydrolysate   6.89 kg/h
                - total MHA   2.76 kg/h
15   - H_2O 0.5 kg/h
                - MIBK/hydrolysate   0.52 [-]

Composition of the MHA hydrolysate:
(prepared in the same way as in example 2, experiment 4)
20

- tot. MHA: 40 wt.%; MHA 94.7 mol-%; dimers + oligomers
  5.3 mol-%
- H_2O: 40.2 wt.%
- SO_4^{2-}:   13.9 wt.%
25 - NH_4^+:   4.85 wt.%

Extraction (001):
Temperature: 52°C (average)
Compositions
30 - of the extraction solution: MIBK   ca. 49.3 wt.%
                                  tot. MHA 35.8 wt.%
                                  H_2O 14.9 wt.%
    - of the raffinate: tot. MHA 0.1 wt.%

35 Evaporation (002):
Pressure: 100 mbar
Sambay - temperature   in the heating jacket: 150°C
                          at the head: 59°C

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<pre>
                              at the bottom: 95°C
          - stripping steam: 0.6 kg/h
          - N₂ stripping gas   100 l/h
          - composition of highly concentrated MHA at bottom
 5   discharge: tot. MHA: 99 wt.%; MHA 94.9 mol-%
                                       dimers + oligomers 5.1 mol-%
                              H₂O: 0.2 wt.%
                              SO₄²⁻:   0.16 wt.%
                              MIBK: 482 ppm
10
</pre>

About 2.8 kg/h of MHA concentrate with the composition given above were obtained at the bottom Sambay discharge point.

15 As a comparison of experiments 1 - 4 shows, an MHA concentrate with ≥ 98 wt.% of total MHA and 0.2 to 2 wt.% of water can be obtained without any product damage occurring [enlarged MHA-(dimers + oligomers) fraction]. This surprising result is shown in a particular way in the
20 MHA concentrates from the low-sulphate MHA hydrolysis solutions (experiments 3 and 4). Here, the MHA-(dimers + oligomers) fraction is only 4.9 - 5.1 mol-%, as compared with 13.1 - 14 mol-% in experiments 1 and 2. The ratio of the proportion by weight of MHA monomers to the sum of
25 dimers + oligomers [= MHA/MHA-(dim+oli)] is about 19 and 6.1 - 6.6 respectively. In all the cases shown here, the MHA-(dimers+oligomers) fraction is thus well under the conventional values for MHA commercial products which have an MHA-(dimers+oligomers) fraction of about 20 - 25 mol-%.
30

In addition, it has been possible crucially to improve the ratio of the MHA/MHA-(dim+oli) proportion by weight as compared with the values given in examples 1 - 6 of patent EP 0 142 488, these being 3.3; 3.2; 3.7 (example 1), 1.8
35 (example 2), 3.0 (example 3), 5.4 (example 5) and 5.2 (example 6).

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Example 4

Preparation of a MHA-methionin-H_2O mixed product from MHA concentrate

5

Experiment 1

Experiment 1 was performed in the same way as example 3, experiment 2 with the difference that the methionin and
10 water were added to the discharge from the bottom of the Sambay evaporator in a stirred tank and a homogeneous solution with 89 wt.% of total MHA[*] and ca. 10 wt.% of water was produced by stirring. For this, 3.2 kg of D,L-methionin (= Met) and 3.2 kg of water were added to a total
15 of 25.7 kg of the MHA concentrate with the composition mentioned, and the mixture was homogenised by stirring. The product produced in this way (32.1 kg) had the following analytically determined composition:

20 total MHA[*]   89.2 wt.% ~ 100.0 mol-%
    MHA monomer   64.8 wt.% ~ 72.6 mol-%
    MHA (dimer +   15.1 wt.% ~ 16.7 mol-%
         oligomer)
    Met   9.2 wt.% ~ 10.7 mol-%
25 SO_4^{2-} 0.8 wt.%
    MIBK   14 ppm

[*] here total MHA = MHA-(monomer + dimer + oligomers) + Met

30 Experiment 2

Experiment 2 was performed in the same way as example 3, experiment 3 with the difference that the methionin and water were added to the discharge from the bottom of the
35 Sambay evaporator in a stirred tank and a homogeneous solution with 88 wt.% of total MHA[*] and ca. 11 wt.% of water was produced by stirring. For this, 3.5 kg of D,L-methionin and 4.0 kg of water were added to a total of

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27.0 kg of the MHA concentrate with the composition
mentioned, and dissolved by stirring. The product produced
in this way (34.5 kg) had the following analytically
determined composition:

5

total MHA[*]	88.1 wt.%	~ 100.0 mol-%
MHA monomer	73.8 wt.%	~ 83.8 mol-%
MHA (dimer + oligomer)	4.3 wt.%	~ 4.9 mol-%
10 Met	10.0 wt.%	~ 11.4 mol-%
SO_4^{2-}	0.16 wt.%	~
MIBK	482 ppm	

[*] here total MHA = MHA-(monomer + dimer + oligomers) + Met

15

Example 5

Preparation of MHA-NH_4 salt solution from MHA concentrate

20 98.3 g of MHA extraction solution with a concentration of
40 wt.% (0.26 mol) of total MHA, 13 wt.% of water and ca.
47 wt.% of MIBK, prepared as in example 3, experiment 1,
was evaporated for 2.4 hours at 55 - 70°C under a water-jet
vacuum. 17.7 g (0.26 mol) of 25 % aqueous ammonia solution
25 was added to the residue (total MHA of 99.9 wt.%). This
caused the temperature to increase to 53°C. After cooling
to room temperature, 57.6 g of a brown, clear liquid with
the following composition was obtained:

30 total MHA	68.3 wt.%
MHA monomer	59.5 wt.%
MHA-amide	0.0 wt.%
MHA-(dimers+oligomers)	8.8 wt.%
NH_4^+	8.1 wt.%
35 H_2O	22.4 wt.%

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Example 6

Preparation of a MHA-NH$_4$ salt solution from MHA extraction solution

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3502 g of MHA extraction solution with a concentration of 35.8 wt.% of total MHA, 14.9 wt.% of H$_2$O and ca. 49 wt.% of MIBK, prepared as in example 3, experiment 4, was cooled to 5°C in an ice bath. Into this solution was passed 300 g 10 (17.6 mol) of gaseous ammonia at a temperature of 5 - 21°C over the course of 3.5 h. Two liquid phases formed. The heavier phase (2202 g) was isolated and residual MIBK was removed by the passage of water vapour at 60°C and 100 mbar pressure. The residue was concentrated at 50°C (2 h) under 15 a water jet vacuum, wherein an oily brown-yellow liquid (1583 g) with the following composition was obtained:

total MHA		81.2 wt.% (= 103 % of theoretical)
incl:	- MHA monomer	79.3 wt.%
	- MHA-amide	1.9 wt.%
	- MHA-(dimers	0.0 wt.%
	+oligomers)	
NH$_4$$^+$		9.0 wt.%
water		9.8 wt.%

25

After dilution with 230 g of water and 20 g of 25 % strength ammonia solution, a very mobile pale brown liquid (1743 g) with the following composition was obtained:

total MHA		70.0 wt.%
incl:	- MHA monomer	68.3 wt.%
	- MHA-amide	1.7 wt.%
	- MHA-(dimers+	0.0 wt.%
	oligomers)	
NH$_4$$^+$		8.1 wt.%
H$_2$O		20.0 wt.%

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Surprisingly, unwanted MHA-(dimers+oligomers) could no
longer be detected in the product solution after this
treatment. Only a negligible amount of MHA-amide was formed
as the single secondary product.

5

Example 7

Preparation of an MHA-MHANH$_4$-H$_2$O mixed product from MHA
extraction solution

10

Experiment 1

Using the conditions essentially given in example 3,
experiment 2, 10 kg of MHA extraction solution with a
15   concentration of 39.7 wt.% of total MHA, ca. 12 wt.% of H$_2$O
and ca. 48 wt.% of MIBK were evaporated in the Sambay
evaporator. The solution being discharged was diluted with
altogether 0.636 kg (3.06 mol) of an 8.2 % strength aqueous
NH$_3$ solution and thoroughly mixed.

20

An oily, brown-yellow liquid (4.60 kg) with the following
composition was thereby obtained (pH - 2.3):

Total MHA		86.2 wt.% (~ 100 % of th.)
25 incl:	- MHA monomer	74.3 wt.%
	- MHA-amide	0.0 wt.%
	- MHA (dimers + oligomers)	11.9 wt.%
	NH$_4$*	1.2 wt.%
30	SO$_4$$^{2-}$	0.22 wt.%
	H$_2$O	13.5 wt.%
	MHANH$_4$*	10.75 wt.%

* Calculated value for proportion of MHA-NH$_4$ proportion
35   (~11.2 mol-% as monomer, dimers and oligomers)

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40

Experiment 2

Using the conditions essentially given in example 3,
experiment 2, 10 kg of MHA extraction solution with a
5   concentration of 35.1 wt.% of total MHA, ca. 12.7 wt.% of
H_2O and ca. 52 wt.% of MIBK were evaporated in the Sambay
evaporator. The solution being discharged was diluted with
altogether 0.45 kg (4.23 mol) of a 16.0 % strength aqueous
NH_3 solution and thoroughly mixed.
10

An oily, brown-yellow liquid (3.96 kg) with a pH of ca. 2.7
and with the following composition was thereby obtained:

Total MHA		88.6 wt.% (~ 100 % of th.)
15 incl:	- MHA monomer	76.9 wt.%
	- MHA-amide	0.0 wt.%
	- MHA (dimers +	11.7 wt.%
	oligomers)	
NH_4^+		1.94 wt.%
20 SO_4^{2-}		0.15 wt.%
H_2O		9.8 wt.%
MHANH$_4$*		17.70 wt.%

* Calculated value for proportion of MHA-NH_4 proportion
25 (~17.7 mol-% as monomer, dimers and oligomers)

Example 8

Determining the Cannon Fenske viscosity:
30

The variation in kinematic viscosities with temperature was
determined, as can best be seen in fig. 2, with an opaque
Canon-Fenske viscometer using the ISO 3105-1976 method, for
the following MHA qualities:
35

• 98 % MHA, prepared as in example 3, experiment 2 and
stored at room temperature for > 300 days, corresponding to
the curve with the reference number 1 in fig. 2.

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* 88 % MHA from 98% MHA, prepared as in example 3,
experiment 2, stored at room temperature for > 300 days and
then diluted to 88 %, corresponding to the curve with the
reference number 2 in fig. 2, and

5

* 88 % MHA as a commercial product, corresponding to the
curve with the reference number 3 in figure 2.

Despite the relatively high dimer and oligomer content
10 directly after dilution with water, the viscosity of the
MHA 88 produced from 98 (2) corresponded to that of the
commercially produced MHA 88 (3).

Example 9

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Storage experiments using MHA products

The products mentioned in figures 3 to 6 were each stored
in a sealed glass vessel without stirring, at the
20 temperatures quoted for a period of up to 310 days. At
regular intervals, samples were withdrawn and the
concentration of total MHA, MHA monomer, MHA (dimers +
oligomers) and optionally Met were determined (see methods
given above).

25

Figure 3

MHA concentrate which was prepared as in example 3,
experiment 2, produced an equilibrium mixture, after about
30 3 month's storage at room temperature, of
47 mol-% MHA monomer (1) and
53 mol-% MHA (dimers + oligomers) (2).

Figure 4

35

MHA 88, which was prepared in the same way as in example 3,
experiment 2 and then diluted with water to 88 % MHA

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content, produced an equilibrium mixture, after about 3
months storage at room temperature, of
74 mol-% MHA monomers (1)
26 mol-% MHA dimers + oligomers (2)

5

This ratio was also found in commercial products.

Figure 5

10   MHA 78 + Met 10 which was prepared as in example 4,
experiment 1 produced an equilibrium mixture, after about 3
months storage at room temperature, of
80 mol-% MHA monomer + Met (1)
20 mol-% MHA dimers + oligomers (2)

15

Figure 6

MHA 78 + MHANH$_4$ 10, which was prepared as in example 7,
produced an equilibrium mixture, after only 14 days storage
20   at 40°C, of
80 mol-% MHA monomers (1) and
20 mol-% MHA dimers + oligomers (2).

A comparison of figures 3, 4, 5 and 6 shows that product
25   mixtures such as MHA 78 + Met 10 or MHA 78 + MHANH$_4$ 10
clearly have more favourable (dimers + oligomers)-fractions
than commercial MHA 88 after prolonged storage. With MHA 78
+ MHANH$_4$ 10 the equilibrium state (caused by elevated
temperature) was reached (figure 6) much earlier than in
30   the other cases shown.

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Patent Claims

1. A process for recovering 2-hydroxy-4-methylthiobutyric
    acid (MHA) in which the MHA is isolated from a
    reaction mixture which is obtained by the addition of
    hydrocyanic acid (HCN) to
    methylmercaptopropionaldehyde (MMP) and hydrolysis of
    the thereby obtained methylmercaptopropionaldehyde
    cyanohydrin (MMP-CH) with sulphuric acid, wherein the
    reaction mixture is placed in contact with an organic
    solvent which is essentially immiscible with water in
    a liquid/liquid extraction system, in order to form an
    extraction solution which contains the solvent and MHA
    transferred from the reaction mixture, and the MHA is
    obtained as an extract from this extraction solution
    by evaporation,
    characterised in that
    the evaporation is performed in such a way that the
    remaining extract contains less than 4 wt% of water.

2. A process according to Claim 1,
    characterised in that
    the organic solvent is removed in an evaporation
    process using a thin layer evaporator, a falling film
    evaporator a short-path evaporator and/or a stripping
    stage or with the assistance of this type of unit.

3. A process according to Claim 1 or 2,
    characterised in that
    the pressure during evaporation is not greater than
    600 mbar.

4. A process according to Claims 1 to 3,
    characterised in that
    the temperature of the MHA as an extract during
    evaporation is not essentially higher than 150°C.

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5. A process according to Claim 4,
characterised in that
the temperature of the MHA as an extract is between 30
and 100°C directly at the outlet from the evaporation
procedure.

6. A process according to one of the preceding Claims,
characterised in that
the residence time of the remaining extract in the
evaporation stage is not longer than 1.5 h.

7. A process according to one of the preceding Claims,
characterised in that
the hydrolysis of the MMP-CH is performed in such a
way that in a first stage the MMP-CH is hydrolysed
with 60 - 85 % strength sulphuric acid in the molar
ratio MMP-CH:H_2SO_4 of 1:0.5 to 1:1.05 at temperatures
of 30 - 90°C with the production of essentially MHA-
amide and this is hydrolysed in a second stage by
adding water without the further addition of H_2SO_4 at
temperatures of up to 140°C.

8. MHA obtainable by a process described in the preceding
Claims, having more than 98 wt.% of MHA calculated as
the sum of monomeric MHA, MHA dimers and MHA oligomers
as well as more than 0.1 and less than 2 wt.% of water
and a kinematic viscosity of > 100 mm^2/s at 25°C.

9. Use of the MHA according to Claim 8 to prepare
mixtures for supplementing animal feedstuffs
characterised in that
a mixture with methionin is prepared, whose MHA
content including monomers, dimers and oligomers is
< 80 wt.% and whose oligomer content including MHA
dimers and oligomers is < 25 mol-%, with respect to
the total active substance content of MHA, dimers and
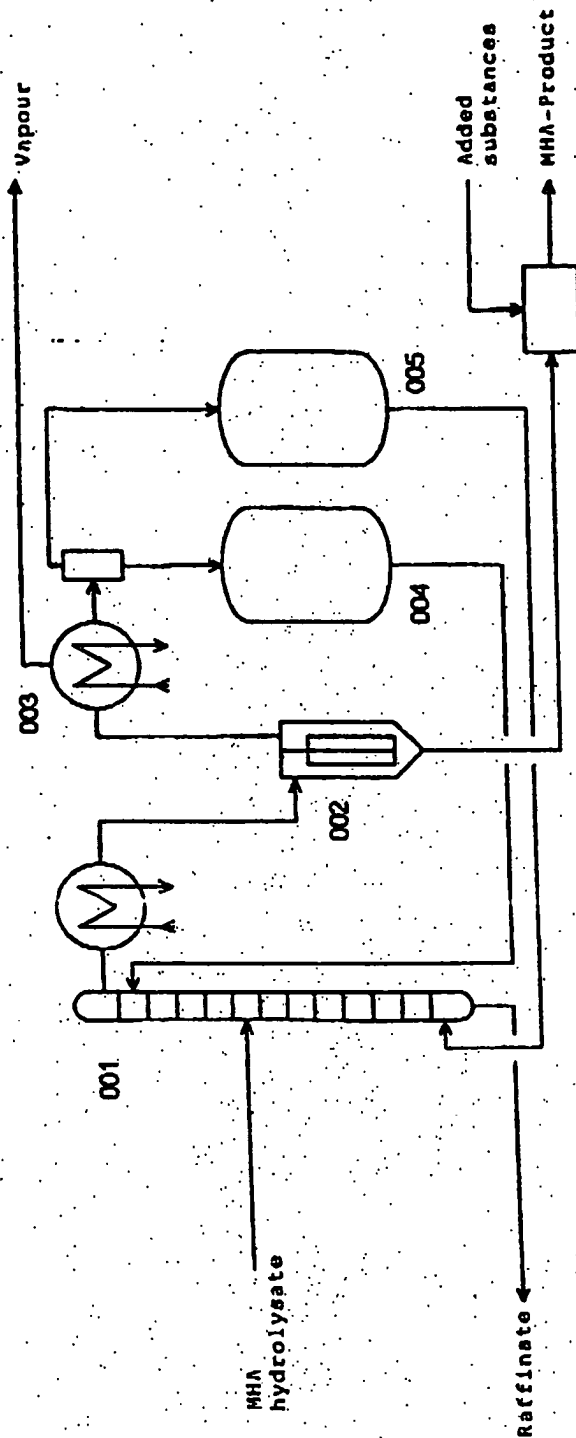oligomers and methionin, after storage for 300 days at
room temperature.

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10. Use of MHA according to Claim 8 to prepare mixture for
supplementing animal feedstuffs,
characterised in that
a mixture is prepared with gaseous ammonia, aqueous
ammonia and/or ammonium MHA, whose MHA content
including monomer, dimers and oligomers is < 80 wt.%
and whose oligomer content including MHA dimers and
oligomers is < 25 mol-%, with respect to the total
active substance content of MHA, dimers and oligomers,
after storage for 30 days at 40°C.

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Figure 1

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Figure 2

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Figure 3

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Figure 4

c / [Mol-%]

100
90
80
70
60
50
40
30
20
10
0

1

2

0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360

t / [d]

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Figure 5

c / [Mol-%]

t / [d]

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Figure 6

c / [Mol-%]

t / [d]